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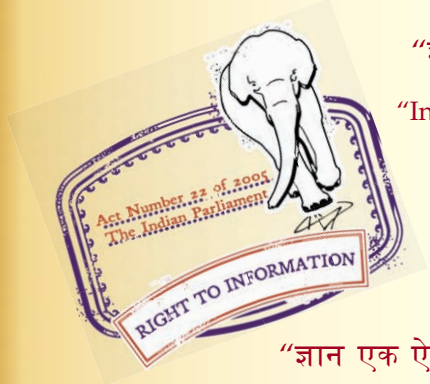
IS 10565 (1999): Diagnostic Audiometers [LITD 7: Audio, Video and Multimedia Systems and Equipment]



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"ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है"
Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

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IS 10565 : 1999
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भारतीय मानक

नैदानिक श्रवणमापियों की विशिष्टि

(पहला पुनरीक्षण)

Indian Standard

SPECIFICATION FOR DIAGNOSTIC AUDIOMETERS

(First Revision)

ICS 13.140

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

March 1999

Price Group 7

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Acoustics Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

The audiometer, covered by this standard, is a device for testing the functioning of the auditory system, by air conduction and bone conduction, with pure tone and speech signals.

The purpose of this standard is to ensure that the threshold tests and supra threshold hearing tests of a given individual on different audiometers, complying with the standard, will give substantially the same results under comparable conditions and that the results obtained will represent a good comparison between the threshold of hearing of the individual and the standard reference threshold hearing, between the responses of the individuals and the responses for similar group of subjects on the supra threshold tests, under earphone listening or sound field conductions. Annex A gives information about correction figures for free field equivalent output for certain types of commonly used earphones.

This standard is being revised to bring it in line with the latest developments at the international level. It is in no way intended to restrict or inhibit development and incorporation of new features, or other improvements, likely to assist the audiologist or otologist. While preparing this standard, assistance has been taken from IEC 60645-2 (1993) 'Audiometers — Part 2: Equipment for speech audiometry', issued by the International Electrotechnical Commission.

The technical committee responsible for preparing of this standard has reviewed the provisions of the following IEC and ISO publications and decided that they may be used in conjunction with this standard:

IEC 318 (1970)	An IEC artificial ear, of the wide bad type, for the calibration of earphones used in audiometry
IEC 373 (1990)	Mechanical coupler for measurements of bone vibrators
ISO 266:1977	Acoustics — Preferred frequencies
ISO 389-4:1994	Acoustics — Reference zero for calibration of audiometric equipment — Part 4: Reference levels for narrow band masking noise

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS 2:1960 'Rules for rounding off numerical value (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

SPECIFICATION FOR DIAGNOSTIC AUDIOMETERS

(First Revision)

1 SCOPE

This standard specifies the requirements and methods of measurements for diagnostic audiometers through monaural and binaural hearing.

2 REFERENCES

The following Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
1885	Electrotechnical vocabulary:
(Part 3/Sec 5) : 1966	Part 3 Acoustics, Section 5 Speech and hearing
(Part 3/Sec 6) : 1967	Part 3 Acoustics, Section 6 Acoustical instruments
4755 : 1987	Reference zero for the calibration of puretone air conduction audiometers (*first revision*)
6964 : 1973	Octave, half-octave and third-octave band filters for analysis of sound and vibrations
9098 : 1979	Specification for pure tone audiometers
9302 (Part 6) : 1986	Characteristics and methods of measurements for sound systems equipment: Part 6 Headphones and head sets
9779 : 1981	Sound level meters
10779 : 1981	Provisional reference coupler for the calibration of earphones used in audiometry
11024 : 1984	Standard reference zero for the calibration of pure-tone bone conduction audiometers and guidelines for its practical application

3 TERMINOLOGY

3.1 For the purpose of this standard, the terms and definitions given in IS 1885 (Part 3/Sec 5), IS 1885 (Part 3/Sec 6) and IS 9098 shall apply in addition to the following.

3.2 Diagnostic Audiometer

The diagnostic audiometer is a dual channel audiometer with complete facility for conducting hearing threshold measurements using pure tones for both air and bone conduction. Among the tests which can be done on this audiometer are SISI, binaural loudness balance tests, pure tone, speech Stenger and SAL tests. With this audiometer speech audiometry may be undertaken with a microphone in channel 1 or tape input on either channel 1 or channel 2, or free field audiometry using either pure tones, speech or noise.

3.3 Hearing Level for Speech

For a specified speech signal and a specified manner of signal presentation, the speech level minus the appropriate reference speech recognition threshold level.

3.4 Speech Level

The sound pressure level or the vibratory force level of the speech signal as measured in an appropriate coupler, ear simulator or in a sound field with specified frequency weighting and specified weighting.

3.5 Reference Speech Recognition Threshold Level

For a specified speech signal and a specified manner of signal presentation, the median value of the speech recognition threshold levels of a sufficiently large number of otologically normal test persons, of both sexes, aged between 18 and 25 years inclusive and for whom the test material is appropriate.

3.6 Coupler Sensitivity, Coupler Sensitivity Level of an Earphone

3.6.1 *Coupler Sensitivity*

At a given frequency, the quotient of the sound pressure generated by the earphone in an acoustic coupler or ear simulator and voltage applied to the terminals of the earphone.

3.6.2 *Coupler Sensitivity Level*

Twenty times the logarithm to the base ten of the ratio of the coupler sensitivity to the reference sensitivity, 1 Pa/V.

NOTE — Coupler sensitivity and coupler sensitivity level of a bone vibrator are defined in a corresponding way.

3.7 Free-Field Sensitivity, Free-Field Sensitivity Level of an Earphone

3.7.1 *Free-Field Sensitivity*

At a given frequency and for at least 10 otologically normal subjects, the quotient of the sound pressure of a frontally incident plane progressive sound wave (0° sound incident) and of that voltage of equal frequency which is applied to the terminals of the earphone in order that the subjects, on average, judge the sound wave and the sound produced by the earphone as equally loud; both sounds being received in the same ear.

NOTE — Though the loudness comparisons may be performed aurally, the resulting sensitivity is that of a single earphone.

3.7.2 *Free-Field Sensitivity Level*

Twenty times the logarithm to the base ten of the ratio of the free-field sensitivity to the reference sensitivity, 1 Pa/V.

NOTE — Free-field sensitivity and free-field sensitivity level of a bone vibrator are defined in a corresponding way.

3.8 Free-Field Equivalent Earphone Output Level

For a speech audiometer, the sound pressure level generated by an earphone in terms of equivalent free-field sound pressure level. At a given frequency, this level is derived from the sound-pressure level generated by the earphone in an acoustic coupler or ear simulator by adding a correction figure representing the difference between the free-field sensitivity level and the coupler sensitivity level for the type of earphone used at the given frequency.

NOTE — See Note under **3.7.1.**

3.9 Free-Field Equivalent Bone Vibrator Output Level

For a speech audiometer, the vibratory force level generated by the bone vibrator in terms of free-field equivalent sound-pressure level. At a given frequency this level is derived from the vibratory force level generated by the bone vibrator on a mechanical coupler by adding a correction figure representing the difference between the free-field sensitivity level and the coupler sensitivity level for the type of bone vibrator used at the given frequency.

3.10 Effective Masking Level for Speech

The level of a specified masking sound which is numerically equal to that hearing level for speech to which the speech recognition threshold level for a specified speech signal for a notional normal person would be raised by the presence of that masking sound. The notional normal person is one whose hearing conforms to the standards for threshold and for masking efficiency (ISO 389 and ISO 889-4).

4 REFERENCE EQUIVALENT THRESHOLD LEVELS

4.1 The standard values of reference equivalent threshold level shall be in accordance with the values given in **3.2** of IS 4755 for earphones and **3.1** of IS 11024 for bone vibrators.

4.2 Output Level Control for Speech Signals

4.2.1 The output level control shall have only one scale and one reference point. It shall be calibrated in intervals of 5 dB less and clearly marked as to whether the scale refers to sound pressure level or hearing level for speech. For types A-E and B-E audiometers, the scale should refer to sound pressure levels (re: 20 micro Pa). In this case, the reference position of the output level control is 20 dB. For types A and B audiometers, the scale should refer to hearing level. In this case, the reference position of the output level control is 0 dB. Type A audiometer provides a wide range of facilities, while type B provides only basic facilities. For both types, the audiometer may be calibrated in terms of a free-field equivalent output level of the earphones and then be designated as type A-E or B-E.

4.2.2 Relative to its reference position, the output level control shall cover atleast a range from –10 dB to 80 dB for loudspeaker output and –10 to 100 dB for earphone output levels.

4.2.3 The manufacturer shall specify the output level range for bone vibrators in terms of either vibratory force level or hearing level.

5 GENERAL REQUIREMENTS FOR AUDIOMETERS

5.1 Signal Level Indicator

5.1.1 A level indicator shall be provided at each channel to monitor all calibration and other input signals.

5.1.2 The level indicator shall have a reference indication towards maximum of the scale and have the response time characteristics of a meter as a VU meter.

5.1.3 The signal level indicator shall be connected at a point in the circuit before the output level control. Provision shall be made in the amplifier for easy adjustment of its gain to compensate for a range of at least 20 dB in the level of input signals. It shall be possible to adjust the level of the calibration signal to the reference indication with an uncertainty of not more than 1 dB.

5.2 Each channel shall be provided with a separate tone switch, each meeting the requirements mentioned below.

5.2.1 The audiometers shall be provided with a keying device (tone switch) of normally 'OFF' type for the presentation of the test tone of the subject by the operator and its operation shall be such as to establish and eliminate the tone without producing audible transients or extraneous frequencies. The key should be easily operable.

NOTES

1 When an automatic keying device is used, its characteristics shall be specified by the manufacturer and care shall be taken that it does not influence the results of the measurements.

2 Facilities for locking device may be provided to keep the tone switch in continuous 'ON' position.

5.2.2 In the 'OFF' position of the tone switch, the steady value of the sound pressure level (SPL) produced by the earphone in an artificial ear shall be least 60 dB below the steady value in the 'ON' position or at least 10 dB below the standard reference equivalent threshold sound pressure level (*see* **4.1**), whichever of these two levels is higher. The build-up and decay time of the tone shall be as given in **5.2.3** and **5.2.4** respectively.

NOTE — It is essential that the presentation of the test tone shall not be accompanied by audible transients or signals of extraneous frequencies or mechanical noise caused by the operation of the controls. An objective formulation of these demands is diffcult but experience shows that, when using the build-up and decay times given in **5.2.3** respectively, no difficulties arise.

5.2.3 When the tone switch is moved to the 'ON' position, the time taken for the SPL produced by the earphone to attain –1 dB, relative to its final steady value shall not exceed 0.2 second from the instant of operating the switch. The time required for the SPL to rise in progressive manner from –20 to –1 dB relative to its final steady value shall not be less than 0.02 second. At no time during the build up or decay of the tone shall the SPL produced by the earphone attain a value exceeding ±1B relative to its steady value in the 'ON' position.

5.2.4 When the tone switch is moved to the 'OFF' position, the time taken from the SPL produced by the earphone to decay from the level of –1 dB to the level of 60 dB relative to its steady value in the 'ON' position shall not exceed 0.2 second from the instant of operating the switch. The time required for the SPL to fall in a progressive manner from –1 dB relative to its steady value in the 'ON' position, shall not be less than 0.02 second.

NOTE — The time taken from the instant of operating the switch in the moment when the SPL has decayed to –1dB relative to its steady value in the 'ON' position, shall be as short as possible and shall not in any case exceed 0.3 second.

5.2.5 At no time after operating tone switch shall the SPL produced by the earphone attain a value +1dB, relative to its steady value in the 'ON' position.

5.3 The potentiometer for rectification of calibration shall be hidden.

5.4 Talk back/talk over system may be provided for immediate contact and communication with the patient during testing excluding any other signal input.

5.5 A patient signal and a non-glaring light on the audiometer front panel to indicate patient response shall be provided.

5.6 Unwanted Sound from an Audiometer

Any sound due to the operation of audiometer controls during the actual listening test, or due to radiation from the audiometer, shall be inaudible at each setting of the hearing level (HL) dial up to and including 50 dB. The test for this requirement shall be made by an otologically normal subject wearing a pair of disconnected earpohones and located at the recommended test position, the electrical output of the audiometer being absorbed in a resistive load equal to the impedance of the earphone at 1 000 Hz. Where a bone conduction facility is available, the test shall be repeated with only one ear occluded by an earpohone.

NOTE — This limitation on noise from controls applies to any noise that could furnish the patient with clue which might influence the test results. It is not intended to apply to a mechanism such as an output selection switch or a detent on the frequency switch, that would emit noise which would occur when the subject is not actually being tested.

6 POWER SUPPLY

6.1 The audiometer shall be capable of operating with the specified requirements either from ac mains or battery or both within the limits of voltages as specified below.

6.1.1 *Battery Operations*

The audiometer shall operate from suitable batteries as specified by the manufacturer. The number and type of cells shall be indicated. The battery shall be housed inside the audiometer itself. The limits of the battery voltages with which the audiometer shall operate shall be specified by the manufacturer.

6.1.2 *Mains Operation*

The auidometer shall operate from 240 V ± 10 percent 50 Hz ac power source. The audiometer shall be provided either with built-in or external eliminator.

7 REQUIREMENTS OF AUDIOMETERS FØR AIR CONDUCTION MEASUREMENT

7.1 Pure Tones

7.1.1 The audiometer shall be capable of generation or producing at least the following test frequencies for which HL values are indicated in Table 1.

Table 1 Output Levels

(*Clauses* 7.1.1, 7.1.3, 7.1.5, 7.2.1, 7.6.1 *and* 7.6.5.1)

Sl No.	Frequency in Hz	Minimum Upper Limit	
		Air dB HL	Bone dB HL
(1)	(2)	(3)	(4)
i)	125	70	—
ii)	250	90	45
iii)	500	120	60
iv)	750	120	60
v)	1 000	120	70
vi)	1 500	120	70
vii)	2 000	120	70
viii)	3 000	120	70
ix)	4 000	120	70
x)	6 000	110	—
xi)	8 000	100	—
	Minimum Value of Output	−10	−10

7.1.2 All the test frequencies shall be available in both channels. Alternatively, test frequencies 500 Hz through 6 000 Hz shall be available in channel 2 and 125 Hz through 8 000 Hz in channel 1.

7.1.3 A separate frequency selector shall be provided for each channel for each of the test tones listed in Table 1.

7.1.4 *Accuracy of Tone Frequencies*

The frequency of each tone shall be constant and accurate to within ±3 percent throughout the presentation.

NOTE — Present control to readjust the frequency and level when deviated from their specified value, may also be provided.

7.1.5 *Harmonic Distortion*

For the frequencies and HL settings listed in Table 1, the maximum level of the harmonics relative to the fundamental of the test tone shall not exceed the values given in Table 2. Distortion shall be measured at the HL listed or at the maximum HL setting on the audiometer, whichever is the lower.

7.1.5.1 For air conduction, distortion shall be measured acoustically on an acoustic coupler or artificial ear.

NOTE — Because of the different frequency responses of earphones on human ears and on acoustic couplers, larger distortion values may occur on human ears than those measured on a coupler at lower frequencies, particularly at 125 Hz.

7.1.5.2 For bone conduction, the distortion shall be measured on a mechanical coupler.

NOTE — Due to non-linearity in the low frequency range of current bone vibrators, reflected in high harmonic distortion products, it is not possible to specify maximum permissible harmonic distortion adequate to ensure that correct bone conduction results are obtained for all types of hearing losses.

7.2 Warble Tones

7.2.1 The audiometer shall provide frequency modulated tones at the test tone frequencies of the hearing level values indicated in Table 1.

7.2.2 The modulation rate of 8 per second, frequency deviation shall be ±10 percent. Other frequency deviation may be provided as an additional feature.

NOTE — There shall be provision for presenting the frequency mechanical tones through the bone vibrator or through loudspeaker separately or alternatively, in free-field.

7.2.3 The frequency-modulated tones at the test frequencies shall be available through one channel. This shall be the channel through which 125 Hz through 8 000 Hz tones are available. As an optional feature, these tones may be available through both channels. It shall be possible to choose to present the modulated tones through both channels simultaneously or through both channels alternatively.

7.2.4 *Accuracy of Warble Tones*

The frequency modulated tones shall be checked for the base frequency, SPL output and distortion.

7.3 Pulsed Tones

7.3.1 There shall be provision for pulsed tones at all the test frequencies through one channel and optionally through both channels. The tones shall have automatic pulsing as well as manual pulsing. The rate of pulsing shall be one cycle per second with 50 percent duty cycle (*see* Fig. 1).

7.3.2 When the pulsed tones are available through both channels, it shall be possible to choose to present pulsed signals simultaneously through both channels or through each channel alternatively.

7.3.3 An indicator shall be provided for each pulse presentation. This may be a flickering light or the deflection of the needle on the level indicator.

7.3.4 For the administration of the SISI test, there shall be a continuous tone with intensity superimposed upon the steady-state tone at periodic intervals. The interval between each superposition shall be 5 seconds. The rise-decay time and the duration of the superimposed signal shall be as depicted in Fig. 2.

The range of intensity of superimposed signal available shall be from 0 to 5 dB in steps of 1 dB. A selector shall be provided to select the desired level of intensity for the superimposed signal with the range provided.

Table 2 Maximum Permissible Harmonic Distortion
(*Clause* 7.1.5)

Sl No.	Frequency Hz	Air Conduction			Bone Conduction		
		125	250 and 8 000	500 to 6 000	250	500 and 750	1 000 to 4 000
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Hearing level, dB	75[1)]	90[1)]	110[1)]	20	50[1)]	60[1)]
ii)	Second harmonic (percent)	2	2	2	10	5	5
iii)	Third harmonic (percent)	2	2	2	5	2	2
iv)	Fourth and each higher harmonic (percent)	0.3	0.3	0.3	2	2	2
v)	All subharmonics (percent)	—	0.3	0.3	—	—	—
vi)	Total harmonic (percent)	3	3	3	12	6	6

NOTES

1 Due to the limitations of acoustic couplers, artificial ears and mechanical couplers, measurements of harmonics occurring at frequencies above 4 000 Hz may not accurately describe the non-linear properties of the system. Electrical measurements should be made across the terminals of the transducers at these frequencies.

2 These distortion values do not necessarily apply to insert transducers; for such transducers electrical determination of distrotion should be made.

[1)] Or relevant maximum output level for the audiometer, whichever is lower.

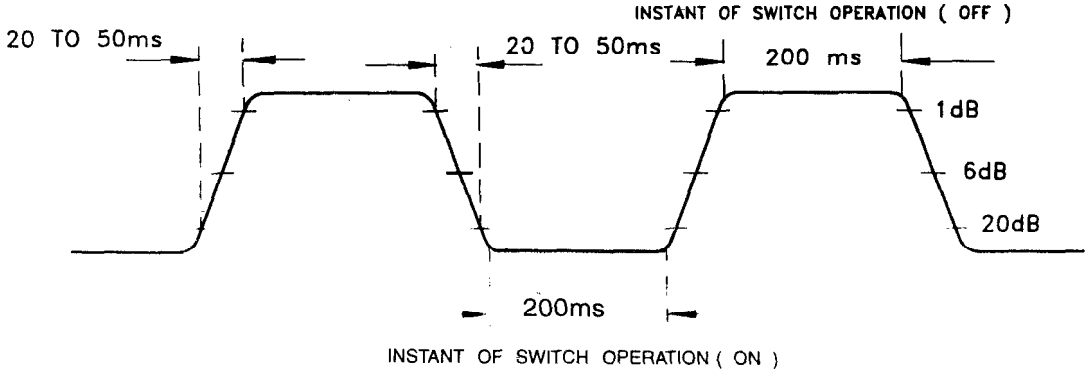

FIG. 1 PULSED TONE CYCLE (GENERAL)

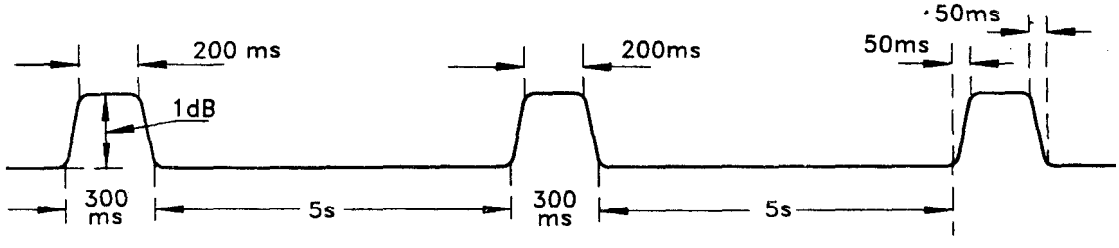

FIG. 2 PULSED TONE CYCLE (FOR SISI TEST)

7.3.5 An indicator for showing when the superposition occurs shall be provided. It may be a flickering light or a deflection of the level indicator needle.

7.3.6 The signal must be calibrated so that the dial readings indicating the intensity of superimposed signal from 0 dB through 5 dB are accurate. It may be checked by sending the output directly from the SISI unit, or by sending the output through earphones and an artificial ear to a graphic level recorder. The checking must be done at each frequency and for each increment setting, from 0 dB through 5 dB.

7.3.7 An automatic counter to indicate the number of presentations at 1 dB modulation and an indicator to record automatically the modulations detected by the patient shall be provided. There shall be a switch for resetting both counters to zero.

NOTE — There shall be no clicks or other distorting influences.

There shall be no clipping of the signal.

7.4 Sound Source

7.4.1 Each audiometer shall be provided with two earphones. Each earphone shall be equipped with ear cushions of supraaural type and shall be provided with suitable springhead band having adequate tension to hold the earphone against the ears to provide a satisfactory seal with a force of atleast 4 N. The earphones shall be so designed that it permits close scaling of the ear with a well designed enclosed air volume. It shall be possible to obtain accuracy of positioning. The right earphone shall be marked red, and the left earphone shall be marked blue.

NOTE — It is desirable that the ear cushion be of a kind which can readily be cleaned.

7.4.2 It shall be possible to present tone, noise or speech signals from either channel to each earphone independently, simultaneously or alternatively.

7.4.3 Provision shall be made for presenting the tone, noise or speech through the earphone, the loudspeakers or through the bone conduction vibrator. When the loudspeakers are the sound source, it shall be possible to present tones or speech through one loudspeaker and noise through the other loudspeaker. It shall also be possible to present the same signal, tone, speech or noise through both loudspeakers. It shall be possible to choose among the 3 types of noise provided by the audiometer for presentation through the loudspeakers.

7.5 Hearing Level Control (Attenuator)

7.5.1 The SPL of each tone shall be adjustable in steps of 5 dB or less throughout the full range of the instrument. One of the settings shall correspond to the HTL for the tone in question (*see* **4.1**). This corresponds to an audiometer hearing loss of 0 dB for the tone.

7.5.2 The hearing level dial shall have a fixed index point and only one scale.

7.5.3 The maximum levels for air conduction and bone conduction shall be indicated on the hearing level dial.

7.5.4 There shall be two attenuators to adjust the level of the signal in each channel separately and independently. For each attenuator, provisions of **7.5.5.1** to **7.5.5.4** shall be applicable.

7.5.5 For one of the channels, provisions shall be made for adjusting the HTL in 1 dB steps.

7.5.5.1 The acoustical measurements for the accuracy of the SPL produced by the earphone should be carried out at 1 000 Hz and at 60 dB. At other settings of the attenuator only the electrical measurements should be carried out.

7.5.5.2 The difference between the acutal SPLs of a tone at two neighbouring settings of the attenuator scale shall be within ±1 dB or by not more than 1/10 of dial separation of the difference between the scale readings at the two settings, whichever is larger. The measurement shall be done at 1 000 Hz.

7.5.5.3 The difference between the actual SPLs of a tone at each pair of settings of the attenuator scale shall be within ±2 dB of the difference between the scale readings at the settings. The measurement shall be done at 1 000 Hz.

7.5.5.4 The overall performance shall be such that the deviation between the actual sound pressure level of a tone, set up by the earphone in an artificial ear, at each setting of the attenuator and the standard reference equivalent threshold sound pressure level, does not exceed the value indicated on the attenuator scale by more than the amount stated below.

The acoustical measurement shall be done at 60 dB at the following frequencies:

Nominal Frequency of the Test Tone	*Maximum Permissible Deviation*
Hz	dB
(1)	(2)
125[1)]	+3
250	+3
500	+3
750	+3
1 000	+3
1 500[1)]	+3
2 000	+3
3 000	+3

Nominal Frequency of the Test Tone	*Maximum Permissible Deviation*
Hz	dB
(1)	(2)
4 000	+3
6 000	+5
8 000	+5

NOTE — If more than one channel for signals and/or noise can be connected simultaneously to a single transducer, the output level of either signal (or noise) from the transducer with both channels connected shall differ by less than ±1 dB from the level obtained when one channel is connected. This requirement shall be met at frequencies from 125 to 4 000 Hz and with a tolerance of ±2 dB at higher frequencies. It shall also apply to hearing levels (HLs) up to 20 dB below the maximum output level.

[1] Optional frequencies.

7.6 Masking Source

Masking source shall be available through both channels. It shall be possible to attenuate the noise in each channel independently.

7.6.1 The audiometer shall provide narrow-band masking sounds for the pure tone signals indicated in Table 1. The noise band centre frequency shall be automatically selected by the pure tone in channel 1 or 2. All measurements of the masking noise levels shall be made acoustically in the coupler or in the artificial ear. Analysis of noise spectum should be performed with a 1/3 octave or a narrow-band analyzer.

NOTE — Masking sounds may also be transmitted through the bone vibrator.

7.6.2 The noise bands shall be centred geometrically around the test tones. The recommended band limits for the masking sound are given in Table 3. The minimum attenuation rate outside the pass band should be at least 12 dB per octave.

7.6.3 *Broad-Band Noise*

Broad-band (random) noise used shall have a spectrum pressure level, as measured in the acoustic coupler or artificial ear, which is uniform within ±5 dB relative to the 1 000 Hz level over the frequency range of 250 to 6 000 Hz.

7.6.4 *Weighted Random Noise for Speech*

The audiometer shall provide weighted random noise for speech and the spectrum pressure level should be constant from 250 Hz to 1 000 Hz with a 12 dB per octave fall off from 1 000 Hz to 6 000 Hz. The above characteristics shall be met within ±5 dB.

7.6.5 *Reference Levels*

7.6.5.1 For narrow-band noise, the level control shall be calibrated in dB of effective masking. The masking noise in each 1/3 octave band centred at the frequencies listed in Table 1, shall have a SPL equal to corresponding reference equivalent threshold level +3 dB at the frequency of the pure tone about which the band is centred.

7.6.5.2 For other noises, the masking level control shall be calibrated in SPL or in effective masking or measured with the earphone on an artificial ear or acoustic coupler.

Table 3 Narrow Band Masking Sounds Upper and Lower Frequency Limits at the 3 dB Points of the Spectral Density

(*Clause* 7.6.2)

Sl No.	Centre Freq.	Lower Limit, Hz		Upper Limit, Hz	
	Hz	*Min*	*Max*	*Min*	*Max*
(1)	(2)	(3)	(4)	(5)	(6)
i)	125	105	112	140	148
ii)	250	210	223	281	297
iii)	500	420	445	561	595
iv)	750	631	668	842	892
v)	1 000	841	891	1 120	1 190
vi)	1 500	1 260	1 340	1 680	1 740
vii)	2 000	1 680	1 780	2 240	2 380
viii)	3 000	2 520	2 680	3 370	3 570
ix)	4 000	3 360	3 560	4 490	4 760
x)	6 000[1]	5 040	5 360	6 740	7 140
xi)	8 000[1]	6 720	7 120	8 980	9 520

NOTE — These band limits correspond to one-third octave as a minimum and one-half octave as a maximum. These bands are wider than the critical bands for effective masking. These bands are recommended to minimize perceived tonality in the masking noise.

[1] Due to the limitations of existing couplers and artificial ears, acoustic measurements are not required.

7.6.6 *Specification of Masking Effect*

For the earphone-earcushion combination used, the manufacturer shall apply data showing the masking effect for each signal and the corresponding SPL on the coupler or artificial ear.

7.6.7 *Accuracy of Masking Levels*

The level of the masking noise produced by an earphone shall be within +5 to –3 dB of the indicated value. The measured difference in output between any two successive designations of masking level shall not differ from the indicated difference by more than 3/10 of the dial interval measured on decibels or 1 dB whichever is smaller. Measurements, for conforming with this requirement, may be made acoustically or electrically at the input to the transducer with the transducer attached to a coupler. Alternatively, the transducer may be replaced by a dummy load which simulates the transducer impedance at that test frequency.

7.6.8 *Masking Level Range*

Masking noise shall be available at levels, at least sufficient to mask tones at 60 dB HL at 250 Hz, 75 dB at 500 Hz, 80 dB from 1 000 to 4 000 Hz and for speech. The overall output SPL of the masking noise shall not exceed 125 dB. The masking noise level shall be adjustable over a range from 0 dB HL to above hearing levels, in steps of 5 dB or less.

8 REQUIREMENTS OF AUDIOMETER FOR BONE CONDUCTION MEASUREMENTS

8.1 Test Tone Frequencies

At least six tones of frequencies, namely 250, 500, 1 000, 2 000, 3 000 and 4 000 Hz shall be provided. The frequency of each tone shall be constant and accurate to within ±3 percent throughout the presentation.

8.2 Contact Area of Bone Vibrators

A bone vibrator shall be provided having a plane circular contact area of 175 ± 25 mm^2.

8.3 Head Band

A specified head band shall be provided to hold the bone vibrator in position and to exert a static force of 5.4 ± 0.5 N. The head band shall permit the simultaneous use of one of the air conduction test earphones as a source of masking noise to the ear not under test.

NOTE — The mastoid is recognized as a suitable location for contact of the vibrator with the head, but this does not preclude the use of other contact locations, like the forehead, provided the location be clearly identified and corresponding calibration data furnished.

8.4 Calibration

The bone vibrator shall be calibrated according to the normal threshold of hearing for bone conduction, using the meachanical coupler. The zero setting of the audiometer hearing-level dial for air conduction shall apply also for bone conduction for a stated placement of the bone vibrator.

8.5 Unwanted Sound from a Bone Vibrator

8.5.1 At any test frequency of 4 000 Hz or lower, and at higher test frequencies, where provided, the bone vibrator shall not radiate sound to such an extent that the sound reaching the test ear by air conduction through the unoccluded ear canal might impair the validity of the bone conduction measurement. As judged by an otologically normal test subject, the sound radiation from the bone vibrator shall be heard at a level at least 10 dB below the level which the vibrator generates by bone conduction when in contact with the head.

8.5.2 A test for conformity with this requirement shall be made as follows:

a) First, the bone conduction threshold is determined in the usual manner.

b) Then, the auditory threshold with the vibrator is determined in approximately the same position except that its normal contact area is covered with a vibration isolation pad providing an attenuation of atleast 20 dB above 1 000 Hz. The attenuation of the isolation pad may be measured on a mechanical coupler. The auditory threshold shall be atleast 10 dB greater than before.

8.5.3 The mean shall be atleast 10 dB greater than before. The mean shall be taken of the results of at least 10 otologically normal ears.

NOTE — The sound radiation of the bone vibrator may be lower in some cases and at some frequencies when loaded with such a pad compared with the radiation when loaded with the human mastoid.

9 INPUT SELECTOR

9.1 With an input selector for each channel, it shall be possible to select the type of input signal, pure tone, warble tone or pulsed tone and mode of presentation of the speech signal, live voice or tape input.

9.2 Input selector for channel 2 shall include all the possible selections available for channel 1. In addition, it shall include an input option, channel, so that whatever input has been selected for channel 1, it may be directed automatically to channel 2. The intensity of the signal shall be controlled independently by means of the two attenuators.

10 REFERENCE TONE FACILITIES

10.1 Means may be provided for alternate presentation of tones of the same or different frequencies via earphones.

10.2 It shall be possible to present the tones alternately and automatically between the two earphones so that the signal of the same or different frequencies is present in each earphone for the same duration. The total duration of the tone in each earphone shall be 500 ms with the rise-decay time of 50 ms each.

10.3 In addition to the hearing level control, by which the SPL of the test tone is adjusted, the second HL control shall permit the control of the reference tone SPL. Operation of the reference tone control shall not influence the output of the test tone.

10.4 The frequency accuracy, distortion, rise-decay and stability of both the test tone and the reference tone, shall be as specified in the relevant sections of the standard.

10.5 All test frequencies from 250 to 6 000 Hz used in air conduction test shall be available as reference tones.

11 REFERENCE TONE LEVEL CONTROL

11.1 Range

The reference tone level control shall cover a range from 0 dB HL to atleast 80 dB HL at 250 Hz and to at least 100 dB HL at 500-6 000 Hz.

11.2 Intervals

Either the test tone level or the reference tone level shall be adjustable in intervals of 2.5 dB or less.

NOTE — The control normally intended for the masking level may be used as the reference tone level control.

11.3 Calibration

The reference tone control shall be calibrated in dB HL.

11.4 Accuracy

For the same HL settings and for the same frequency, the SPL of the reference tone shall be within ± 3 dB of the test tone level for frequencies between 500 Hz and 4 000 Hz. For the remaining frequencies a deviation of ±5 dB is acceptable.

12 SPEECH AUDIOMETRY

The audiometer shall be capable of presentation of speech through live voice or tape input. The minimum upper limit of the speech input through earphones shall be at least 100 dB.

12.1 Electroacoustics Source for Speech Audiometry

The primary signals comprise of spoken material. Using appropriate transducers such as microphones, recording heads and pick ups, these signals may be stored on a magnetic or other tape for subsequent use or may be applied directly to the audiometer amplifier as live voice. A meter shall be provided to verify that the output has a known or a predetermined level.

If the audiometer has the means of replaying recorded speech material as an intergral part of it, tests for conformity shall be performed using a recording of the test signals required. If the replaying device is not an integral part of the audiometer, the test signals shall be applied to the electrical input of the audiometer.

12.2 Standard Reference Threshold SPL for Speech

The relationship between the elements of the speech audiometer shall be such that the scale markings of the attenuator will indicate zero HTL for speech when a calibrating tone of 1 000 Hz brings the monitor meter to its standard reference deflection and simultaneously produces an SPL from the earphone equal to the standard reference threshold SPL for speech.

12.3 Accuracy of Sound Pressure Levels (SPL) for Speech Audiometry

The sound pressure levels produced by the earphone as referred to in standard reference threshold level shall not differ from the indicated values by more than 3 dB. Measurement for compliance with this requirement shall be made by combining an acoustical measurement of SPL at a 60 dB dial setting with the results of interval measurements made as mentioned above.

12.4 Reference Conditions for Specification, Testing and Calibration of Speech Audiometers

For the results of earphone and bone vibrator speech audiometry using types A-E and B-E audiometers to be comparable to those of loudspeaker free-field testing, or to the results from using different types of transducers, free-field equivalent measuring conditions shall be used.

For type A and B audiometers where there is no requirement to maintain such comparability, the uncorrected earphone/bone vibrator coupler measurements shall be used to specify and test the characteristics of the speech audiomter.

12.4.1 *Free-Field Equivalent Earphone Output Level*

For types A-E and B-E audiometers, the output sound pressure level and overall frequency response of the

speech audiometer including the earphone shall be specified in terms of free-field equivalent sound-pressure level.

NOTE — The basic method for measuring the free-field equivalent sound pressure level of earphones is described in IS 9302 (Part 6). Routine calibrations may be performed using an acosutic coupler or ear simulator and applying correction figures for the difference between the free-field sensitivity level and the coupler sensitivity level for the type of earphone under test. Annex A gives suggested correction figures for certain types of commonly used earphones.

12.4.2 *Uncorrected Earphone Output Level*

For types A and B audiometers with supraaural earphones, the output sound-pressure level and overall frequency response of the speech audiometer including the earphone shall be specified in terms of uncorrected sound-pressure level measured in an acoustic coupler according to IS 10779 or an ear simulator according to IEC 318. For other types of earphone, the manufacturer shall specify the method of measurement.

12.4.3 *Loudspeaker Output Level*

Output sound-pressure level and overall frequency response of the speech audiometer including the loudspeaker shall be specified as measured in a free-field at a distance of 1 m on the reference axis of the loudspeaker.

NOTE — The performance measured under reference conditions may not apply in conditions other than in a free-field and at a distance of 1 m.

12.4.4 *Free-Field Equivalent Bone Vibrator Output Level*

For types A-E and B-E audiometers, the output vibratory force level and overall frequency response of the speech audiometer including the bone vibrator shall be specified in terms of free-field equivalent sound-pressure level. If corresponding data for the type of bone vibrator used does not exist, the specification shall be in accordance with **12.4.5**.

12.4.5 *Uncorrected Bone Vibrator Output Level*

For types A and B audiometers, the output vibratory force level and overall frequency response of the speech audiometer including the bone vibrator shall be specified in terms of uncorrected vibratory force level measured on a mechanical coupler according to IEC 373.

12.4.6 *Calibration Signal*

The specifications and test methods for speech audiometers are based on the assumption that the calibration signal level of the recorded speech material is the same as the average level of the materials when measured in a specified manner.

12.4.7 *Output Sound-Pressure Level and Vibratory Force Level*

For the reference conditions in **12.4** and at the reference position of the output level control, the calibration signal shall produce a sound-pressure level (re: 20 micro Pa) of 20 dB ±2 dB when the calibration signal causes the level indicator to be at its reference point.

For uncorrected bone vibrator outputs the corresponding vibratory force level (re: 1 micro N) shall be 55 dB ± 5dB.

NOTE — A sound pressure level of 20 dB and a vibratory force level of 55 dB corresponds approximately to the reference speech recognition threshold level for easily recognizable test material presented monaurally

12.4.8 *Frequency Response*

12.4.8.1 *Overall frequency response of the audiometer*

For the reference conditions given **12.4** and for the test conditions given **12.4.8.2**, the output sound-pressure level generated by the loudspeaker or earphone with any test signal in the frequency range from 250 to 4 000 Hz shall not differ by more than ±3 dB from the average sound-pressure level of all test signals in this range. For any test signal in the range below 250 to 125 Hz, the tolerance is +0 to −10 dB and above 4 000 to 6 300 Hz it is ±5 dB.

If the audiometer has the means of replaying analogue-recorded speech material as an integral part of it, the tolerance shall be increased by ±1 dB within the range from 250 to 4 000 Hz and ±2 dB outside this range but within the range from 125 to 6 300 Hz.

NOTE — Higher long term stability and closer frequency response tolerance may be obtained by the use of digital recorded speech material and corresponding replay device.

For the bone vibrator output, the manufacturer shall specify the frequency response and tolerance in the range from 250 to 4 000 Hz.

12.4.8.2 *Test conditions*

If the audiometer has the means of replaying recorded speech material as an integral part of it, the test shall be performed using a recording of test signals of equal level filtered from white noise by third-octave filters according to IS 6964 centred at the preferred third-octave frequencies according to ISO 266. If the replaying device is not an integral part of the audiometer, the same test signals as above shall be applied to the electrical input of the audiometer. The manufacturer shall specify how conformity with the requirements of **12.4.8.1** is to be established for the complete equipment including an external replaying device.

The level of the test signals shall be adjusted to provide the reference indication of the signal level indicator for the test signal centred at 1 000 Hz. The output level control of the audiometer shall be set to 70 dB for earphone and loudspeaker outputs, and 40 dB for bone vibrator output.

For the measurement of loudspeaker, earphone and bone vibrator output levels, the reference conditions of **12.4** shall apply.

The output sound pressure level generated by the earphone shall be measured in an acoustic coupler or ear simulator as specified by the manufacturer. For types A-E and B-E audiometers, correction figures representing the frequency dependent difference between the free-field sensitivity level and the coupler sensitivity level for the type of earphones used shall be added to the measured coupler sound-pressure levels before applying the tolerance. For certain types of earphones, these correction figures are given in Annex A. For other types of earphones, they shall be specified by the manufacturer.

The manufacturer shall specify methods for testing the bone vibrator output level with respect to the reference conditions of **12.4.4** and **12.4.5** respectively.

12.4.8.3 *Microphone input frequency response*

For the test conditions given in **12.4.8.4**, the output voltage level generated at the terminals of the microphone for any input test signal within the frequency range from 125 to 8 000 Hz shall not differ by more than ±3 dB from the average level of all test signals in this range.

If the audiometer is equipped with a network to compensate for the frequency response of a microphone that does not conform with the above, for example because the microphone is housed in the audiometer case, the manufacturer shall provide means for assuring that the microphone together with its compensating network,comforms with the requirements.

12.4.8.4 *Test conditions*

The test shall be performed under free-field conditions using test signals of a constant sound-pressure level (re: 20 micro Pa) of 80 dB filtered from white noise by third-octava filters according to IS 6964 centred at the preferred third-octave frequencies according to ISO 266. The manufacturer shall state how the microphone is to be used (for example, angle of incidence) to meet the requirements of **12.4.8.3**.

12.4.9 *Harmonic Distorion*

12.4.9.1 *Earphone output*

For the reference conditions given in **12.4** the total harmonic distortion of the signal generated by the earphone output shall not exceed 2.5 percent. This shall be measured with a pure tone applied to the electrical input of the audiometer at the test frequencies 250 Hz, 500 Hz and 1 000 Hz and at a level 9 dB above the reference indication of the signal level indicator (**4.1**) at an output sound pressure level (re: 20 micro Pa) of 110 dB.

12.4.9.2 *Loudspeaker output*

For the reference conditions given in **12.4.3**, the total harmonic distortion of the signal generated by the loudspeaker shall not exceed 3 percent. This shall be measured with the same input conditions as in **12.4.9.1**, but at an output sound pressure level (re: 20 micro Pa) of 80 dB. The total harmonic distortion shall be less than 10 percent at 100 dB output sound- pressure level for the same frequencies.

12.4.9.3 *Bone vibrator output*

For the test conditions given in **12.4.9.1**, the manufacturer shall state the total harmonic distortion at the stated maximum output level of the bone vibrator.

12.4.10 *Signal-to-Noise Ratio*

At an output level control setting of 70 dB and with level of the recorded calibration signal set to the reference indication of the signal level indicator, the voltage at any transducer input terminal, measured with frequency weighting A according to IS 9779 shall be at least 45 dB higher than that obtained when the replay system is stopped in a pause mode. The manufacturer shall specify how conformity with this requirement is to be achieved if the replay system is not supplied with the speech audiometer.

NOTE — This test includes measurement of the performance of the replay system, the audiometer and any external amplifiers.

12.5 Noise

12.5.1 The electrical background noise from all sources other than surface noise of the recordings shall be atleast 50 dB below the level of the signal as mentioned in the following manner.

12.5.1.1 The amplifier shall be adjusted so that the meter indicates the reference level when the input is a 1 000 Hz signal from a record, or in the case of a live-voice speech audiometer, when a 1 000 Hz signal at 85 dB SPL is delivered to the mircorphone. The output SPL of the audiometer shall be measured with the above input signal and with the attenuator at the 100 dB HTL setting.

12.5.1.2 The output SPL shall be measured with no signal input to the audiometer, and with the attenuator set at the 100 dB HTL. In testing with a magnetic tape playback, the mechanism is activated but no tape is run across the pick up. In testing a live-voice

type of audiometer, the microphone shall be protected as is feasible from any acoustic input, or a dummy microphone may be used.

12.5.2 The pressure level measured under condition given in **12.5.1.2** shall be at least 50 dB the pressure level measured under conditions given in **12.5.1.1**.

12.6 Sound-Pressure Level (SPL) of Speech

The sound-pressure level of a speech signal at the earphone is defined as the rms sound pressure at the level of 1 000 Hz signal adjusted so that the level indicator deflection produced by the 1 000 Hz signal is equal to the average peak level indicator deflection produced by the speech signal. The level indication of the level indicator for a preliminary carrier phrase may be taken as the level indication of the immediately following speech materials when the material is delivered in a natural manner at the communication level as the carrier phrase.

12.7 Live-Voice Input

The frequency response characteristics of a live-voice channel shall be such that with the microphone in a free-sound field having a constant SPL (approximately 74 dB), the SPL developed by the audiometer in the acoustic coupler or the artificial ear in the frequency band from 250 to 4 000 Hz does not differ from that at 1 000 Hz by more $\pm$10 dB and shall not rise at any frequency outside this band by more than 15 dB relative to the level at 1 000 Hz.

NOTE — A suitable microphone either built in or external shall be provided.

12.8 Recorded Speech Input

The frequency response characteristic of recorded speech channel shall be such that when used with an appropriate test recording of sine waves, the SPL developed by an audiometer in the acoustic coupler or the artificial ear in the frequency band from 250 to 6 000 Hz shall not differ from that at 1 000 Hz by more than $\pm$5 dB and shall not rise at any frequency outside this band by more than 10 dB relative to the level at 1 000 Hz. Conformity with this requirement shall be made at an output SPL of approximately 100 dB (re: 20 micro Pa).

NOTE — It is recommended that a test recording of a calibrated reference signal be supplied to calibrate the speech signal.

12.9 Overall Distortion

With pure tone input having a harmonic distortion not exceeding 1 percent, and with the speech channel amplifier delivering a signal 9 dB above the standard reference deflection of the monitoring meter, the total harmonic distortion in the output of the audiometer, as measured in an acoustic coupler or artificial ear, shall not exceed 3 percent.

Tests for conformity with this requirement shall be made with the hearing level control set to the maximum output, or so as to produce an SPL of 120 dB (whichever is less). These tests shall be conducted at 250, 500, 1 000, 2 000 and 4 000 Hz.

12.10 Monitor Earphone or Loudspeaker

The sound pressure level (re: 20 micro Pa) produced by the monitor earphone or loudspeaker shall be adjustable to meet the need of individual testers, for example, from 50 to 90 dB, and shall be independent of the setting of the output level control and shall not have any influence on the test signals.

12.11 Talkback System

A talkback system is used to listen to the subject's verbal response to test material. It consists of microphone, normally positioned near the subject, an amplifier with a level control and an earphone or loudspeaker output by the tester. A talkback system is required on A and A-E audiometers. No specification is given for this facility but it should have sufficiently good reproducing qualities to enable a wide range of speech level to be clearly heard.

13 INSTRUCTION MANUAL

Each audiometer shall be provided with an instruction and service manual. The instruction manual shall contain the following information:

a) Installation of the equipment,

b) Operation of the equipment,

c) Special test procedures,

d) Rotuine maintenance of the equipment (including calibration of reference levels for the transducers used for that audiometer), and

e) Technical specifications.

ANNEX A

(*Foreword*, and *Clauses* 12.4.1 and 12.4.8.2)

CORRECTION FIGURES FOR FREE-FIELD EQUIVALENT OUTPUT FOR CERTAIN TYPES OF COMMONLY USED EARPHONES

The difference between the free-field sensitivity level G_F and the coupler sensitivity level G_c for four types of audiometric earphones using one-third octave bands of noise as test signals are given in Tables 4 and 5 as a function of centre frequency. The data were obtained under binaural listening conditions, but the results are equally applicable for monoaural speech audiometry. These figures have to be added to measured data of sound-pressure levels produced by an earphone of given type in an acoustic coupler according to IS 10779 or an ear simulator according to respective earphone.

The figures apply under the following conditions:

a) Beyer DT 48 earphones shall be used with flat cushions when applied to the human ear or to the ear simulator. The cushion shall, however, be removed and an adaptor used as described by. H. Rass and H.G. Diestel in Acustica, vol 9, pp.61-64 (1959) when placed on the acoustic coupler.

b) Telephonics TDH 39 and TDH 49 earphones shall be used with MX 41/AR (or model PN 51) cushions on the human ear, on the ear simulator and on the coupler.

c) Pracitronic DH 80 earphones shall be used with flat cushions on the human ear, the acoustic coupler or the ear simulator.

d) When the earphone is applied to the human ear, the headband used shall provide a nominal static force of (4.5 ± 0.5) N.

e) The earphone shall be applied to the ear simulator or the coupler without acoustic leakage with a normal static force (4.5 ± 0.5) N. not including the weight of the earphone itself.

Table 4 Difference Between the Free-Field Sensitivity Level G_F and the Coupler Sensitivity Level G_c for Four Types of Earphones Using an Acoustic Coupler According to IS 10779 and Third-Octave Bands of Noise as Test Signals (Values Rounded Off to the Nearest Half Decibel)

Sl No.	Centre Frequency (Hz)	$G_F - G_c$ (dB)			
		Byer DT48 with Flat Cushion	Telephonics TDH 39 with MX 41/AR or PN 51 Cushion	Telephonics TDH 49 with MX 41/AR or PN 51 Cushion	Pracitronic DH80 with Flat Cushion
(1)	(2)	(3)	(4)	(5)	(6)
i)	125	−16.5	−17.5	−21	−19.5
ii)	160[1)]	−15	−14.5	−18	−17
iii)	200[1)]	−13	−12	−15	−15
iv)	250	−11	−9.5	−12	−13
v)	315[1)]	−9	−6.5	−8	−10.5
vi)	400[1)]	−7	−3.5	−4.5	−8
vii)	500	−5	−0.5	−1	−3.5
viii)	630	−3	0	0	−2
ix)	800	−2	−0.5	−1	−2
x)	1 000	−2.5	−0.5	−2	−2.5
xi)	1 250	−1.5	−1	−1.5	−3
xii)	1 600	−5.5	−4	−5.5	−7
xiii)	2 000	−7.5	−6	−7.5	−8
xiv)	2 500	−7.5	−7	−8	−7.5
xv)	3 150	−6.5	−10.5	−9	−8
xvi)	4 000	−5	−10.5	−9.5	−8.5
xvii)	5 000	−1.5	−11	−8.5	−6
xviii)	6 300	−3.5	−10.5	−10.5	−9
xix)	8 000	−2	+1.5	−5	−2

[1)] Values for these frequencies are derived by interpolation.

Table 5 Difference Between the Free-Field Sensitivity Level G_F and the Coupler Sensitivity Level G_c for Four Types of Earphones Using an Ear Simulator According to IEC 318 and One-Third Octave Bands of Noise as Test Signals (Values Rounded off to the Nearest Half Decibel)

(*Annex A*)

Sl No.	Centre Frequency (Hz)	$G_F - G_c$ (dB)			
		Byer DT48 with Flat Cushion	Telephonic TDH 39 with MX 41/AR or PN 51 Cushion	Telephonic TDH 49 with MX 41/AR or PN 51 Cushion	Pracitronic DH80 with Flat Cushion
(1)	(2)	(3)	(4)	(5)	(6)
i)	125	−14	−16	−19	−17
ii)	160[1)]	−13	−14	−17	−16
iii)	200[1)]	−12	−12	−14.5	−15
iv)	250	−11	−10	−12	−14
v)	315[1)]	−9.5	−7	−9	−11.5
vi)	400[1)]	−7.7	−4	−5.5	−8.5
vii)	500	−5.5	−1.5	−2.5	−5.5
viii)	630	−4	−0.5	−1	−3.5
ix)	800	−2.5	−1	−2	−3
x)	1 000	−3	−1.5	−3	−3
xi)	1 250	−2	−1.5	−2	−3.5
xii)	1 600	−6.5	−5	−6.5	−8.5
xiii)	2 000	−10	−7	−9	−11
xiv)	2 500	−12	−7.5	−10.5	−12.5
xv)	3 150	−12	−10.5	−12.5	−13
xvi)	4 000	−10.5	−11.5	−13	−12
xvii)	5 000	−5.5	−7.5	−8.5	−7.5
xviii)	6 300	−6.5	−17	−12	−11.5
xix)	8 000	−2.5	−6.5	−7.5	−6

[1)] Values for these frequencies are derived by interpolation.